Genetic algorithm based Different Re-dispatching Scheduling of Generator Units for Calculating Short Run Marginal Cost in Deregulated Environment

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***Abstract*— Proper pricing of active power is an important issue in deregulated power environment. This paper presents a flexible formulation for determining short run marginal cost of synchronous generators using genetic algorithm based different re-dispatching scheduling considering economic load dispatch as well as optimized loss condition. By integrating genetic algorithm based solution, problem formulation became easier. The solution obtained from this methodology is quite encouraging and useful in the economic point of view and it has been observed that for calculating short run marginal cost, generator re-dispatching solution is better than classical method solution. The proposed approach is efficient in the real time application and allows for carrying out active power pricing independently. The paper includes test result of IEEE 30 bus standard test system.**

***Keywords*— Short run marginal cost, genetic algorithm, economic load dispatch, loss optimization.**

I. Introduction

In a restructured power industry, Electricity transmission and distribution are considered natural monopolies, whereas generation and retailing are open to competition. Open access to the generation system and fair, cost reflective pricing of generation are very imperative for healthy competition in the power sector. Short run marginal cost (SRMC) in deregulated environment is calculated from optimal power flow (OPF) solution. Economic load dispatch (ELD) problem is the sub problem of OPF. The main objective of ELD is to minimize the fuel cost while satisfying the load demand with transmission constraints. The classical lambda iteration method is the base to solve the ELD problem. This method is used equal increment cost criterion for systems without transmission losses and penalty factors using B-coefficient matrix for considering the losses.

In the past few years the interest in charging methodology has become more pronounced. Many techniques have been adopted and used to solve this problem. Pricing method such as postage stamp, contract path, and megawatt mile are applied [1-2]. The various rate structures have sought improvements in a wide range of social objectives including the cost of electricity generation, reliability of supply, utility profits and even income distribution [3-7], but these methods are only applicable to regulated environment, these are not produce any significant pricing scheme in open access system. In the context of deregulated electricity market, many literatures show marginal cost of wheeling transactions and non-utility generation options using OPF [8], calculation of SRMC for power production taking into account of real and reactive powers [9]. A mathematical model of electric power system has been developed to understand marginal prices for consumers and generators in competitive generation market and verified with a practical power system [10]. Different methods of transmission pricing for wheeling transactions [11] is also adopted.

This paper introduces an alternative approach to determine SRMC using genetic algorithm based different redispatching solution followed by calculating SRMC for each generator. Using genetic algorithm, three types of optimization problems have been solved i.e. one simple ELD problem, loss optimization problem as well as loss optimization maintaining ELD constraint. In each and every optimization problem, one re-dispatching scheduling of generator units has been found. It has been observed that calculating SRMC in open environment, re-scheduling gives better result compare to conventional ELD problem. One of the advantages of genetic algorithm is that it is a parallel process because it has multiple offspring thus making it ideal for large problems where evaluation of all possible solutions in serial would be too time taking. Application of the proposed pricing formulation is demonstrated on the IEEE30 bus systems. The results have also been compared with the conventional method of solution of the ELD problem and shown that proposed re-dispatching method is more significant than classical one.

In section 2, the proposed GA based ELD formulation as well as loss optimization techniques together with SRMC expressions are derived. Section 3 demonstrates the application of proposed formulation on IEEE 30 bus test systems. Conclusion follows in section 4.

A. Nomenclature

In the analytical model following symbols have been used:

$F_{c_{total}}$: Cost function of an N-bus power systems having NG number of fossil fuel units

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N : Number of buses

α, β, γ : Cost coefficients

B_{ij} : Loss coefficients for active power

ϕ : Power factor angles of bus load

δ : Phase angles of bus voltages

P_D : Real power demands

P_G : Real power outputs

P_L : Real loss .

R_{ij} : Series resistance of lines

λ_{p_i} : Lagrangian multiplier for active power balance at the ith bus

$g(x,u)=0$: Equality constraint

$h(x,u)\le 0$: Inequality constraint

ε : Tolerance limit

ρ_i : Short run marginal cost for ith bus

Suffix i stands for ith bus while suffix j stands for jth bus. The variables have been expressed in p.u. while the angles have been expressed in degree.

II. GA based re-scheduling with SRMC

Genetic algorithm (GA) is a global adaptive search technique based on the mechanics of natural genetics. It is applied to optimize existing solutions by using methods based on biological evolution presented by Charles Darwin. It has many applications in certain types of problems that yield better results than the commonly used methods. To solve a specific problem with GA, a function known as fitness function needs to be constructed which allows different possible solutions to be evaluated. The algorithm will then take those solutions and evaluate each one, deleting the ones that show no promise towards a result but keeping those which seem to show some activity towards a working solution.

A. Problem formulation considering power flow requirements within GA

In this paper, comparison study of short run marginal cost calculation is made and analyzed with three different re-sheduling techniques, namely economic load dispatch, loss optimization within power flow and loss optimization technique with maintaining economic load dispatch constraint. The respective fitness function for three different optimization problems is given hereunder.

1) Economic load dispatch problem

The objective function being the total cost of power generation, we have

$$GC(x,u) \text{ i.e.. } \sum_{i=1}^{NG} F_c(P_{G_i}) \tag{1}$$

Subject to

$$g(x,u)=0 \tag{2}$$

$$h(x,u)\le 0 \tag{3}$$

Where

$$F_{c_{total}}\left(=\sum_{i=1}^{NG} F_{c_i}\right)=\sum_{i=1}^{NG}\alpha_i\left(P_{G_i}\right)^2+\beta_i P_{G_i}+\gamma_i \tag{4}$$

The equality constraints (2) are the power flow equations, while the inequality constraints (3) are due to various operational limitations. The limitations include lower and upper limits of generator power capacity.

2) Loss optimization problem

The active loss is conventionally expressed using B-coefficient (or loss coefficient) matrix and can be represented as,

$$P_L=\sum_{i=1}^{n}\sum_{j=1}^{m}P_{Gi}B_{ij}P_{Gj}$$

$$=B_{00}+\sum_{i=1}^{n}B_{i0}P_{Gi}+\sum_{i=1}^{n}\sum_{j=1}^{m}P_{Gi}B_{ij}P_{Gj} \tag{5}$$

For a system of N-plants, the loss coefficients are given by :

$$B_{ij}=\frac{\cos(\theta_i-\theta_j)R_{ij}}{\cos\phi_i\cos\phi_j\,|V_i||V_j|} \tag{6}$$

$$B_{00}=\sum_{i=1}^{n}\sum_{j=1}^{m}P_{Di}B_{ij}P_{Dj} \text{ And } B_{i0}=-\sum_{j=1}^{m}(B_{ij}+B_{ji})P_{Dj}$$

Constraints are considered to be

$$P_{G_i}^{\min}\le P_{G_i}\le P_{G_i}^{\max} \tag{7}$$

and

$$\varepsilon=\sum_{i=1}^{n}P_{G_i}-P_D-P_L \tag{8}$$

3) Loss optimization with ELD constraint

This paper proposed a new generation re-scheduling where loss optimization problem is taken as a fitness function for GA based solution where a new constraint is included, i.e. ELD constraint, in a single optimization problem. Fitness function for this problem is same as discussed in equation number (5) and (6) where as a different constraint function is incorporated with other constraints mentioned in equation number (7) and (8). Penalty factor has been selected as the constraint function, and is given by equation number (9).

$$\frac{dF_c(P_{G_i})}{dP_{G_i}}\left[\frac{1}{1-\frac{\partial P_L}{\partial P_{G_i}}}\right]=\lambda \tag{9}$$

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According to the marginal cost theory, the marginal price ρ_i for active power injection at bus **i** is

$$\rho_i = \lambda - \lambda \frac{\partial P_L}{\partial P_{G_i}} \qquad \text{for } i = 1,2,\ldots\ldots,n \qquad (10)$$

i.e. for SRMC for active power at a generator bus has two components, the first is the increment cost and the second is in proportion to the system production cost rate multiplied by the incremental loss caused by transmitting active power to this bus.

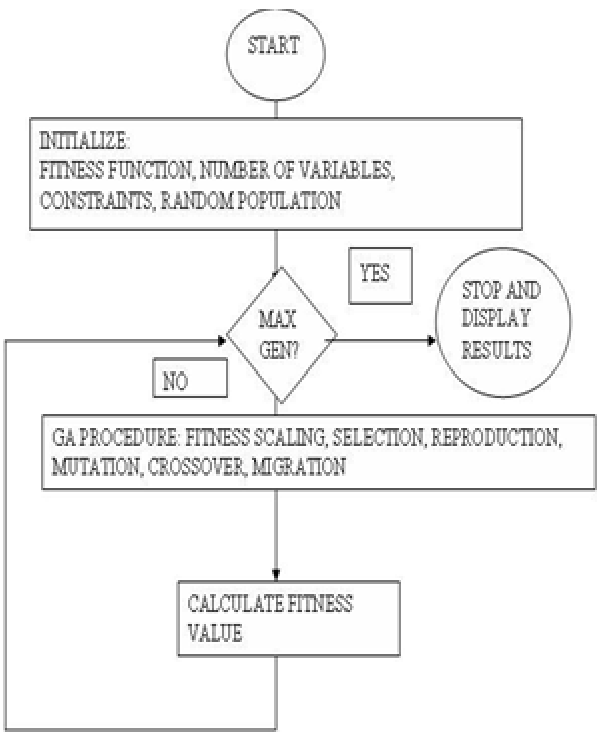

Figure 1. Flowchart of the proposed optimization procedure

III. Analysis and comparison with example

To examine the validity of GA model for proposed re-dispatching scheduling of the power generation of the participating generators as well as SRMC calculation in the deregulated electricity market, IEEE 30 bus test system has been considered. The respective test system details are given in table I and II. Table III shows different re-dispatching scheduling of four types of condition denoted in types 1 to 4. All the generating powers are in p.u. basis and for each condition Lagrange multiplier and B-coefficient are kept constant for power balancing. The incremental loss cost and respective short run marginal cost of the generators for each operating condition are given in table IV.

Table I. Test system properties

Number of buses	30
Number of units	6
Number of branches	43
Number of tie lines	6
Total power demand in pu	2.83

Table II. Production units' properties

Generator no	P_{max} pu	P_{min} pu	Cost Co-efficient		
			α_i	β_i	γ_i
1	0.5	1.5	.01	.4	32
2	0.5	0.7	.02	0.6	60
3	0.1	0.4	.07	.095	45
4	0.1	0.5	.02	1.8	30
5	0.1	0.3	.02	3	31
6	0.1	0.3	.02	3	32

Table III shows different types of rescheduling, where first three scheduling are computed using genetic algorithm whereas forth one is classical method economic load dispatch. For each scheduling, system operating loss is also computed. It has been observed that for GA based scheduling, loss is less compared to classical method. Moreover, in between three types of scheduling, loss is minimum in third type of optimization, where not only system loss is optimized, ELD condition is also fulfilled.

In table IV, Incremental loss cost as well as short run marginal cost are calculated for each scheduling denoted in table IV. It has been observed again that incremental loss cost is much lesser in GA based scheduling compared to classical one. Between three GA based optimization, proposed scheduling where loss optimization and ELD both are maintained, computed lesser incremental loss cost compared to other GA based optimization. As soon as loss cost is decreased, short run marginal cost of the generating units as well as total plant's marginal cost is increased. This observation can be conveyed a good economic message to the generation companies in deregulated environment to determine a new open access pricing scheme for generating units.

Table III. different re-dispatching scheduling of generator units

Types	Condition	Gen 1 (p.u.)	Gen 2 (p.u.)	Gen 3 (p.u.)	Gen 4 (p.u.)	Gen 5 (p.u.)	Gen 6 (p.u.)	Loss (p.u.)
1	GA based ELD	1.49986	0.60058	0.20058	0.20058	0.20172	0.20058	0.067
2	GA based Loss Optimization	1.17446	0.5002	0.38197	0.46505	0.28115	0.10007	0.06289
3	GA based Loss Optimization considering ELD Constraint	1.23108	0.50001	0.14426	0.49426	0.18429	0.10001	0.0608
4	Classical Method ELD Scheduling	1.3848	0.5756	0.2456	0.35	0.179	0.1689	0.07

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TABLE IV. INCREMENTAL LOSS COST AND SRMC FOR GENERATING UNITS

Generator Number	Different Operating Condition							
	GA based ELD		GA based Loss Optimization		GA based Loss Optimization considering ELD Constraint		Classical Method ELD Scheduling	
	Incremental Loss cost (INR/MWhr)	Short run Marginal Cost (INR/MWhr)	Incremental Loss cost (INR/MWhr)	Short run Marginal Cost (INR/MWhr)	Incremental Loss cost (INR/MWhr)	Short run Marginal Cost (INR/MWhr)	Incremental Loss cost (INR/MWhr)	Short run Marginal Cost (INR/MWhr)
1	0.0542	1.4521	0.0453	1.4610	0.047	1.4593	0.0511	1.4552
2	0.0202	1.4861	0.0188	1.4875	0.0188	1.4875	0.0277	1.4786
3	0.0148	1.4915	0.0172	1.4891	0.0140	1.4923	0.0187	1.4876
4	0.0145	1.4918	0.0176	1.4887	0.0181	1.4882	0.0205	1.4858
5	0.0148	1.4915	0.0158	1.4905	0.0146	1.4917	0.0169	1.4894
6	0.016	1.4903	0.0148	1.4915	0.0148	1.4915	0.0176	1.4887
Total Cost	0.1345	8.9033	0.1295	8.9083	0.1273	8.9105	0.1525	8.8853

IV. CONCLUSION

This paper proposes a genetic algorithm based different power generation scheduling, i.e. economic load dispatch scheduling, loss optimized scheduling and a new scheduling where loss optimization as well as ELD constrained are maintained for calculating optimized short run marginal cost for each generating unit with incremental loss cost. For each optimization problem LaGrange multiplier and B-coefficient of the system are kept constant. These features can be used for further studies of recovering generating cost by gencos in open access. The GA based solution has been found suitable for calculation of SRMC of synchronous generators in deregulated environment which is fundamentally different from those existing literature.

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